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Assessing the changes in international trade of marine fishes under CITES regulations – A case study of seahorses

Ting-Chun Kuo*, Amanda Vincent

Project Seahorse, Institute for the Oceans and Fisheries, The University of British Columbia, 2202 Main Mall, Vancouver, Canada V6T 1Z4

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ABSTRACT

Trade regulations may be useful for conserving marine species that are suffering from overexploitation. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has emerged as an instrument to help tighten fisheries management. However, the impacts of CITES regulations have not been examined for the trade in fully marine fishes. This study used seahorses (*Hippocampus* spp.), the first fully marine fishes listed in CITES Appendix II since treaty inception, as a case study. Drawing on Customs data from Taiwan and Hong Kong SAR (which cover pre-CITES periods), iterative-segmented regressions were applied to investigate changes in seahorse trade corresponding to CITES interventions. Principal component analyses were conducted to understand characteristics of seahorse source countries, and a gravity model of trade was applied to identify predictors of seahorse trade volumes. This study found that the total weight of seahorses in documented trade decreased significantly after CITES implementation, recorded trade became concentrated in fewer countries, and prices increased. Seahorse source countries were found having more fishers, demersal fish catch and general trade with China, compared to other range states. However, countries that reported no exports, unchanged export volumes or declining volumes after CITES were similar. In addition, volumes traded between two countries were found significantly higher when the two countries were closer together or when the source country had a lower per capita GDP or higher demersal catch. This study can help guide targeted actions to maximize CITES effectiveness for marine species.

1. Introduction

Commoditization of wildlife has shifted the driver of wildlife exploitation away from supporting livelihoods toward supporting local and global markets [23], and increased the scale of exploitation to an extent that it poses a significant threat to species survival. Over-exploitation from activities such as logging, hunting, and fishing, directly leads to population declines and habitat destruction as evidenced by the more than 2700 animal species listed as near-threatened or threatened on the IUCN Red List [35]. Wildlife is extracted not only for subsistence use, but also for local and international timber, food, medicine, fashion and pet markets, among many others. The global value of imports of wildlife products was estimated in 2009 at about USD323 billion, coming from trade in tens of thousands of species [22]. Monetizing the value of species could accelerate the exploitation rates of wild animals and plants [17]. For example, despite a long history of local consumption of Sunda pangolins (*Manis javanica*) and Burmese starred tortoise (*Geochelone platynota*), increasing international market demands have driven these species to near extinction in just a few decades (both species are now considered Critically Endangered on the IUCN Red List).

When trade expands to global levels, its large-scale and asymmetric nature results in disproportionate exploitation among different regions, and difficulties in management [12,18]. Globalization allows consumers to access natural resources across borders. When demand increases beyond what a country can provide, buyers would seek new suppliers in other countries [9]. Such exploitation expansion has been well documented in the trade of many species, including sea cucumber [3] and sea urchin [4]. Following the expansion in trade, serial depletion has been identified in several local resources (e.g., [39]). In addition, industrialized countries consume an unequal proportion of traded environmental resources when compared to less developed countries [55]. This typically leads to over exploitation of natural resources in developing countries because of the lack of capacity and resources to manage such exploitation [13]. While the supply and demand of international trade are separated from local management efforts, collaborations among national governments are urgently required to conserve global biodiversity.

* Corresponding author.
E-mail addresses: t.kuo@oceans.ubc.ca (T.-C. Kuo), a.vincent@oceans.ubc.ca (A. Vincent).

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The largest collaboration for regulating the complicated international wildlife trade is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) [54]. The main purpose of CITES is to ensure the sustainability of wildlife under the globalization of trade [14]. Species listed in different CITES Appendices are according to the degree that they are threatened by trade [14]. Trade in Appendix I species is basically prohibited, while the trade of species in Appendix II has to be accompanied with permits and determined not detrimental to the wild populations. Appendix III includes species that one range state (countries where the species occurs) has asked other countries to assist in protecting their sustainability. To respond to CITES' requirements, countries have used various methods to control their wildlife supply, including limiting the number of hunting licenses, closed seasons, and bans [43,6]. However, if and how those efforts lead to changes in trade are still unclear.

To date, evaluations of changes in wildlife trade linked to CITES listings have varied across countries and species. Multiple factors have been associated with changes in trade under CITES, such as source countries' capacity in improving management and historic/cultural value of the trade to stakeholders [21,44]. For example, for the amphibian and reptile species listed in CITES Appendix II, their trade volume of wild animals has declined globally [38,44]. This was due in part to the success of ranching and captive-breeding activities [38,44]. Such increases in captive-bred animals mostly happened in the countries where funding and expertise are available [29,44]. In addition, increased retail prices have also been documented for various CITES species, including mammals, amphibians, and reptiles [12,17]. However, previous studies about the impacts of CITES regulations on trade have mainly focused on terrestrial species. Currently it is still unclear how CITES may affect the trade of marine fishes – one of the biggest groups that suffer from over-exploitation.

Can CITES also provoke changes in the trade of marine fishes? If so, what are the determinants of such changes? In 2014, more than 78% of seafood products, of which 81 million tonnes were wild-caught marine fishes, entered international trade [23]. Analysis of FAO trade data for fisheries products indicated that bilateral trade volume was determined by geographical distance between two countries, the production volume of the source country, per capita consumption in the destination country, and regional trade agreements [37]. But when there is a global trade restriction, do these factors still associate with the variations in trade volume? Previous analyses of the effects of food safety standards set by the United States, Japan and European Union found such restrictions in seafood imports benefit developed countries rather than developing countries [2,8]. Trade regulations for combatting illegal fishing, e.g., EU's "yellow cards", were not found to have impacts on the sources of seafood imports, at least not when the analysis was done in 2014 [20]. However, trade sanctions on selected countries issued by regional fisheries management organizations (e.g., ICCAT) have resulted in decreasing imports of regulated fish species from those states [31]. Since 2002, an increasing number of marine fishes have been proposed for CITES listing [16,54]. However, the impact of CITES on the global trade patterns of marine fishes has not been studied.

Seahorses (*Hippocampus* spp.), the first marine fishes listed in CITES Appendix II since its inception, serve as an invaluable example to examine the impacts of CITES on trade. Seahorses are mainly traded dry for traditional medicine and curios, but also live for aquarium uses. Around 37 million dried seahorses are caught incidentally by non-selective gears each year, and the trade is widely occurring across the globe with as many as 80 countries involved [24,32,54]. All seahorse species were listed in CITES Appendix II in 2002, and the listing was implemented in mid 2004. Customs records from two major seahorse markets, Hong Kong and Taiwan, contain seahorse import data from the pre-CITES period (1983 and 1998, respectively) and provide an opportunity to investigate the changes in seahorse trade coinciding CITES interventions.

This study aims to investigate if and how CITES affects the trade volumes, prices, and trade routes of marine fishes, using seahorses as a case study. Moreover, different country-level characteristics were examined across countries to find indicators for the changes in each country's seahorse exports. This study focuses on the trade of wild, dried seahorses, which accounted for 97% of all seahorses reported in trade [24]. The hypotheses in this study are: the global trade volume of seahorses would decline and the supply of seahorses would be dominated by few countries after CITES listing, because countries that were unable to ensure the sustainability of their trade would have to suspend their exports. In contrast, prices would increase since the demand was not satisfied by the decreased volumes.

2. Methods

To identify the changes in trade after CITES interventions, seahorse trade data were collected from two Customs datasets and the CITES trade database. Then, country attributes were examined to determine if they were associated with (1) whether a range state reported as exporting seahorses; (2) whether exports from a seahorse source country were reported as significant dropping or stopping after CITES implementation; and (3) the bilateral trade volumes. The datasets and analyses are described as follows.

2.1. Trade data

Three independent data sets were used to examine the changes in global seahorse trade over time: (1) import and re-export data from Hong Kong Census and Statistics Department (CSD) [30], (2) import data from Taiwan Customs (https://portal.sw.nat.gov.tw/APGA/GA03, accessed October 31, 2015), and (3) the CITES trade database (http://trade.cites.org, accessed June 24, 2016). While Hong Kong and Taiwan data include both import quantity and price of dried seahorses, CITES data include only the quantity traded.

The data from Hong Kong Census and Statistics Department were sourced from 1998 to 2014 (CSD, Hong Kong Department of Census and Statistics 2015). The analyses of Hong Kong's data focused on the imports from the Countries of Origin – countries where products were produced or had undergone the last permanent transformation [30]. Countries of Consignment, the products' last stop before Hong Kong, were not considered in this study because they were usually not the sources of seahorses [30]. The import prices in CSD statistics were converted from Hong Kong Dollars to US Dollars, based on the exchange rate of each year, (http://www.usforex.com, accessed June 20, 2016,). Note that Hong Kong CSD data are independent of Hong Kong's reports to CITES, since CSD are Customs records and CITES reporting in Hong Kong is controlled by the Agriculture, Fisheries and Conservation Department (AFCD). The reports from AFCD are based on the CITES permits submitted by the importers and re-exporters.

Seahorse trade data from Taiwan's Customs covers 1983–2014 (https://portal.sw.nat.gov.tw/APGA/GA03, accessed October 31, 2015). Taiwan's data included the annual dried seahorse import weights from the origin and the import values (in USD), however the import values in the dataset were only broken down by country after 2002. The annual import values were divided by the import weights to calculate the mean price per kilogram for seahorses from each country. Since Taiwan is not a member of CITES, the Customs data is independent to the data in the CITES database. The data of seahorse traded to or from Taiwan in the CITES database are reported by CITES members.

The data for global dried seahorse trade were extracted from the CITES trade database (http://trade.cites.org, accessed June 24, 2016) for 2005–2013, to examine the global pattern of seahorse trade in the post-CITES period. The CITES data before 2005 were excluded in the analyses, since CITES implementation for seahorses started in May 2004 and prior to this countries were not required to report their trade. Only commercial trade of *Hippocampus* species was considered, and the analyses were only done for the trade of wild dried seahorses (97% of total dried trade). In the database, the records with the terms 'bodies', 'derivatives', 'specimens' and 'skeletons' were considered as dried seahorses [24]. Following the instructions above, we extracted 660 entries of declared seahorse trade in the CITES trade database. All analyses for CITES data, if not stated specifically, were performed on the Exports from Imports data (EFI, defined in Foster et al. [24]), which were the larger volume of the reports from exporters and importers when they did not match. For each data entry, if there was no unit reported, it was assumed that the unit was individual as per UNEP-WCMC guidelines, except for the ones clarified by the reporting countries [24].

2.2. Analysis

2.2.1. Changes in declared seahorse trade after CITES listing

The Hong Kong CSD and Taiwan Customs data, which cover pre- and post-CITES listing periods, were used to examine the following four changes in declared seahorse trades corresponding to CITES interventions: 1) total weight of seahorses in trade, 2) number of source countries, 3) evenness of the seahorse supply among source countries, and 4) import price. The two CITES interventions tested were: the listing of *Hippocampus* spp. in Appendix II in 2002, and implementation of the listing in 2004.

Iterative segmented regressions [49] were conducted for each trade variable (total weight of seahorses in trade, number of source countries, evenness of the supply and import price), to test if there was a sharp change in the data from a certain time point, and whether the breakpoint corresponded to CITES interventions. The model for the regression is:

$$V_t = a_0 + a_1 Year_t + a_2 Year_t \times I + a_3 I \quad (1)$$

For which the trade variable (V) was regressed with time ($Year$). Dummy variable I is 1 if $Year$ is smaller or equal to the breakpoint of interest, and 0 if $Year >$ the breakpoint. Because of the sample size restrictions, the breakpoints tested were from 2003 to 2007 for Hong Kong's data, and 2000–2007 for Taiwan's data. The "best" breakpoint was iteratively searched for the model that has the highest r-square value. The "best" breakpoint was hypothesized at 2005, the year after CITES implementation.

The evenness of seahorse supply was measured by the Gini Index [25]. Supply is more uneven if the Gini Index is closer to one, and is more even if the index is closer to zero. The Gini index was calculated over time for each data set separately, and all source countries that ever existed in that dataset were considered in the calculation for each year. Although the segmented regression was only applied on Hong Kong and Taiwan's data, the Gini index for CITES data was still calculated for comparison.

2.2.2. Linking country-level characteristics to changes in seahorse exports

Three main questions were explored to understand how country-level characteristics might correlate with reported seahorse exports. First, why some seahorse range states – countries with one or more seahorse species found within their exclusive economic zone [51] – were documented seahorse exporters, while others were not? Second, what are the differences in characteristics of source countries between the ones that purportedly continued trade and those that stopped exports after CITES implementation? Third, how did the characteristics of source and destination countries correlate to bilateral seahorse trade volumes?

2.2.2.1. Why were some seahorse range states documented seahorse exporters, while others were not?

A principal component analysis (PCA) was conducted to determine the key characteristics that differentiate the range states reported as seahorse sources and those that were not. Seahorse sources were sovereign states reported as exporting seahorses in any of the Customs or CITES datasets (1983–2014).

The following five country characteristics were considered in the PCA (see also Supplemental information A): 1) demersal fish catch volume by the country's vessels; 2) distance from China (the main market of dried seahorses); 3) the annual value of a country's trade in general goods with China; 4) number of fishers working in marine fisheries (including commercial and artisanal fishers); and 5) per capita GDP.

The 1) demersal fish catch was used to represent potential seahorse catch for each country. Adult seahorses are demersal and mainly obtained as bycatch [32], so demersal fish catch was predicted to be positively correlated with seahorse bycatch. China is one of the most important market for dried seahorses, and so 2) the distance between China and the reported source country, together with 3) their bilateral trade in other goods, served as indicators of the country's accessibility to the Chinese market. The distance between China and the other country was calculated as the distance between the two countries' "center of population." That is, the center of a country was weighted by the relative position of the distributed population in each country (considering the 25 cities of more population) [28]. The 4) number of fishers in marine fisheries was an indicator of the fishing effort. Finally, the 5) average per capita GDP was to represent the wealth of each country.

To align with the time series of seahorse trade data, the attribute data were collected from 1983 to 2014. This was only possible, however, for per capita GDP. Data for the demersal catch and trade with China was only obtained from 1983 to 2013 and 2005 to 2014, respectively. The mean of those attribute time series was taken for the PCA. Each country's marine fisheries employment was only estimated for 2003 [48]. The sources of data used to determine country characteristics, and details of each attribute are described in Supplemental information A.

2.2.2.2. Why did some source countries purportedly continue exports after CITES implementation, while others reportedly stopped or had significant declines in exports?

To investigate if countries that reportedly stopped exporting seahorses after CITES implementation had different characteristics than the countries that supposedly continue trade, a principal component analysis was conducted. The data from Hong Kong CSD, Taiwan Customs and CITES were combined to determine all countries with a reported history of commercial trade in dried seahorses ($n = 33$). Source countries were considered to have "stopped" exports if they had no records of exporting seahorses post-CITES in any of the three datasets, or had a dramatic drop in reported trade (the mean annual reported volume in post-CITES period dropped to < 10% of the mean volume of pre-CITES period) in reported imports to Hong Kong or Taiwan ($n = 22$). The remaining countries ($n = 11$) were considered to have continued exporting seahorses after CITES implementation.

Three hypotheses related to the country-level characteristics of a change in behavior with CITES implementation were explored. First, countries might stop issuing export permits for seahorses if they were unable to ensure sustainable trade. In such cases, there may not be enough capacity and/or funding to manage their national fisheries. Second, countries might have more motivation to continue issuing the permits if there were more people involved in the national fisheries. Third, countries might continue to issue permits if there was historically high seahorse export volume.

Six variables that were likely to be linked to a change in behavior after CITES implementation were examined in the PCA: 1) demersal fish catch, 2) per capita GDP, 3) beneficial subsidies to sustainable fisheries [47], 4) fisheries capacity-building subsidies ([47]), 5) number of fishers in marine fisheries, and 6) seahorse export volumes before CITES implementation (using Hong Kong imports as representatives). Because seahorses are mainly bycatch in demersal fisheries, the 1) demersal fish catch would indicate the level of the demersal fisheries requiring management. The 2) per capita GDP, 3) beneficial subsidies, and 4) fisheries capacity-building subsidies were considered as indicators for a country's financial capacity for implementing CITES. The two types of subsidies: 3) beneficial subsidies (investments in managing sustainable fisheries) and 4) fisheries capacity-building subsidies (for building a bigger boat, fuel supply, etc.) were separated, because they might indicate the different attitude of a government toward managing its fisheries [47]. The number of fishers in marine fisheries 5) represented the number of fishers involved in the fisheries, and 6) pre-CITES seahorse exports represented the importance of seahorse trade to a country.

2.2.2.3. What determined the reported trade volume between two countries before and after CITES implementation?. To identify the predictive variables for seahorse trade volume, a gravity trade model [19,37] was fitted to Hong Kong's CSD imports, Taiwan Customs, and CITES data. For Hong Kong and Taiwan Customs data, the model was applied to pre- and post-CITES data separately. Despite recognizing that the declared trade volume might be under-reported, the declared volume was assumed to be proportional to the real volume and represented the relative trade volume among countries. The reported trade that was from unknown sources was excluded in this analysis.

The gravity model of trade describes the bilateral trade volume as a logarithm relationship with country characteristics. For the trade volume between two countries i and j (x_{ij}), the following eight predictors were tested: the geographical distance between two countries ($Dist_{ij}$); GDP per capita of source ($GDPPC_i$) and destination ($GDPPC_j$); number of fishers in the marine sector ($Fpop_i$ and $Fpop_j$); demersal fish catch ($Dcatch_i$ and $Dcatch_j$); and year ($Year_t$).

The model is structured as below:

$$\begin{aligned} \ln x_{ijt} \ = \ & a_1 + a_2 \ln Dist_{ij} + a_3 \ln Fpop_{it} + a_4 \ln Fpop_{jt} \\ & + a_5 \ln GDPPC_{it} + a_6 \ln GDPPC_{jt} + a_7 \ln Dcatch_{it} \\ & + a_8 \ln Dcatch_{jt} + a_9 Year_t \end{aligned} \quad (2)$$

where ijt represents the value of a variable for source i and destination j in a given year t.

Two challenges with using a gravity model had to be overcome in order to analyze these data. First, the trade between two countries may also be influenced by trade interactions among other countries [5]. This is commonly referred to as multilateral resistance term (MRT). A MRT was therefore added to the model using Baier-Bergstrand first-order Taylor-series approximation [5] to account for the multilateral resistance for the explanatory variable "*distances*". Second, while the gravity models typically could not account for zeros because they were logarithmic, a small value (10^{-10}) was added to the zero trade to incorporate small trade volumes that were hardly detected [33].

3. Results

3.1. Changes in declared seahorse trade after CITES

Hong Kong CSD and Taiwan Customs data both showed that declared weights of dried seahorse imports to the two major markets declined in the post-CITES period. For Hong Kong, the decline in import weights started in 2005, the year after CITES implementation. In contrast, the imports to Taiwan had the highest change in trend at 2001, suggesting the imports started decreasing before the CITES listing (Table 1 and Fig. 1). Based on Hong Kong CSD data, mean annual imports decreased from 21.9 t of dried seahorses during the pre-CITES period (1998–2004) to 7.1 t per year (2005–2014). Similarly, imports to Taiwan also decreased, as the Taiwan Customs data shows a mean of 1.3 t annual imports in the pre-CITES period (1983–2014), to only 0.9 t after CITES implementation. CITES records, reported by exporters or importers, were consistent with the trend observed using Customs data (Fig. 1).

Hong Kong CSD showed that the number of declared source

Table 1
Results of testing the CITES interventions as breakpoints for the global seahorse trade using iterative segmented regressions ($V_t = a_0 + a_1 Year_t + a_2 Year_t \bullet I + a_3 I$). Each year from 2003 to 2007 and from 2000 to 2007, for Hong Kong and Taiwan respectively, was tested as the breakpoint in each model. Here only the results from the model with the highest r-square are shown, with p-value of each coefficient estimate in the brackets. The results of other models (with breakpoint as other years tested) are shown in Supplemental information B. HK: data from Hong Kong CSD (1998–2014); TW: data from Taiwan Customs (1983–2014).

		Breakpoint (year)	r^2	Year, a_1	Slope change, a_2	Intercept change, a_3
Annual weight of imports (kg)	HK	2005	0.92	2521 **(< 0.01)**	− 3807 **(< 0.01)**	7,614,557 **(< 0.01)**
	TW	2001	0.78	323 **(< 0.01)**	− 1017 **(< 0.01)**	2,033,704 **(< 0.01)**
Number of source countries	HK	2005	0.92	0.57 **(0.05)**	− 0.88 **(0.01)**	**1756 (0.01)**
	TW	2005	*0.80*	− 0.04 (0.30)	− 0.21 (0.11)	417.33 (0.11)
Evenness in supply	HK	2006	0.82	0.00 **(0.03)**	− 0.00 (0.14)	7.53 (0.14)
	TW	2002	0.63	0.00 **(< 0.01)**	0.01 **(< 0.01)**	**− 12 (< 0.01)**
Price (USD/kg)	HK	2007	*0.61*	− 0.00 (0.96)	0.25 **(0.04)**	− 0.00 **(0.04)**

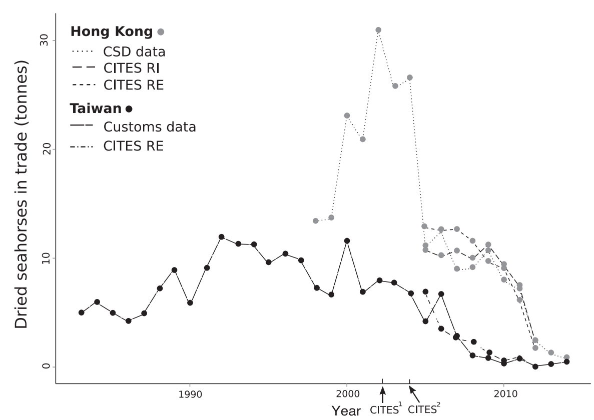

Fig. 1. Changes in the weight of traded seahorses (kg) over time. Import data from Hong Kong CSD and Taiwan Customs were compared to the reports from export countries (RE) and import countries (RI) in the CITES database for years after 2005. The year of CITES listing (2002, CITES[1]) and implementation (2004, CITES[2]) are labeled.

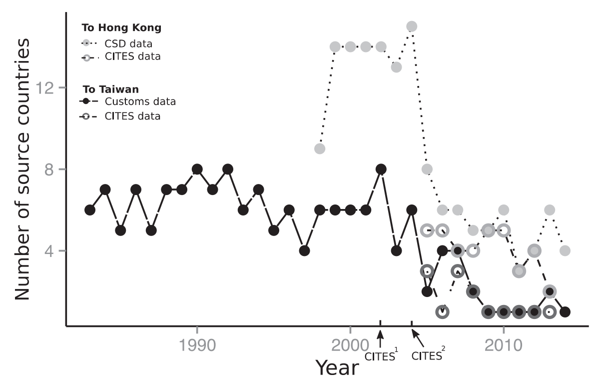

Fig. 2. Number of source countries of dried seahorses for Hong Kong and Taiwan. Data from the CITES trade databases considered reports from both export and import countries (Exports from imports). The year of CITES listing (2002, CITES[1]) and implementation (2004, CITES[2]) are labeled.

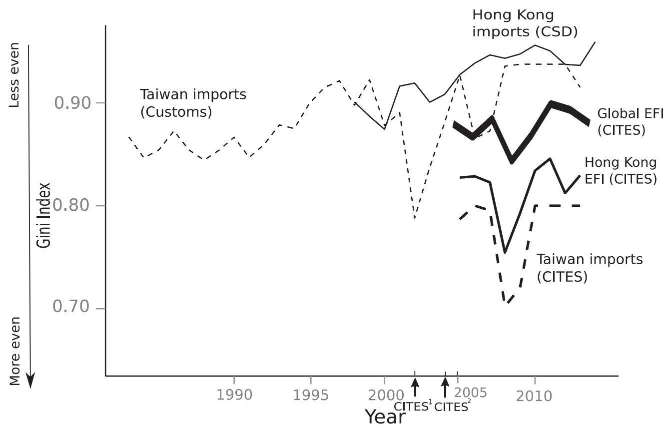

Fig. 3. Evenness (Gini Index) of the supply of dried seahorses for Hong Kong, Taiwan (CSD/Customs data and CITES data) and global trade (CITES data). The higher Gini index indicates less even supply. The year of CITES listing (2002, CITES[1]) and implementation (2004, CITES[2]) are labeled.

countries decreased after 2005, the year after CITES implementation, while the trend in Taiwan Customs data did not significantly change (Table 1 and Fig. 2). Hong Kong reported sourcing from a mean of 13 countries in each year during the pre-CITES period to 5 in the post-CITES period (Fig. 2). Taiwan's imports were reportedly sourced from a mean of 6 countries p.a. before CITES implementation, but only 2 countries for each year after 2005 (Fig. 2). In addition to the declines in the number of source countries, the seahorse supply became concentrated in very few countries (Table 1 and Fig. 3). The evenness in supply to Hong Kong has slightly declined but that trend started before CITES implementation, with no change in slope over time (Table 1 and Fig. 3). The evenness in supply of Taiwan's imports declined significantly faster after 2002 (increases in Gini Index) (Table 1 and Fig. 3).

The composition of source countries for both Hong Kong and Taiwan has changed after the CITES listing and implementation (Fig. 4). Thailand became a more dominant supplier of dried seahorses after 2004 (Figs. 4 and 5). Moreover, an expansion in source countries from Asian to African countries was found after 2004, for both Hong Kong and Taiwan. However, the source countries were replaced by Asian countries again after 2010 (Fig. 4). For Hong KongCSD data, there was not only the composition and supply share changed in the source countries, but also in its re-export destinations, as the re-exports via Hong Kong to mainland China dropped greatly after CITES listing (Fig. 5).

Import prices in Hong Kong have increased significantly since 2007 (Table 1 and Fig. 6). The prices of Taiwan's imports have also increased over time, although there was no sufficient sample size to test the CITES listing and implementation (Fig. 6). The rate of price increase was higher in Asian source countries than in other regions, especially Africa (Fig. 6).

3.2. Linking country-level characteristics to changes in seahorse exports

3.2.1. Why were some seahorse range states documented seahorse exporters, while others were not?

There was a large degree of overlap between the distribution of seahorse source countries and non-source countries on the PCA map, suggesting they shared similar countries characteristics (Fig. 7). However, source countries generally had higher demersal catch, more people employed in marine fisheries, shorter distances from China and more trade with China, compared to the seahorse non-source countries (Fig. 7).

3.2.2. Why did some source countries purportedly continue exports after CITES implementation, while others reportedly stopped or had significant declines in exports?

Countries that continued issuing seahorse export permits after CITES tended to have lower per capita GDP and higher pre-CITES trade, however their country attributes were generally similar to other source countries (Fig. 8).

3.2.3. What determined the reported trade volume between two countries before and after CITES implementation?

The results of the gravity model were consistent between the pre-CITES and post-CITES periods for Hong Kong's imports (Table 2). However, while the model identified two predictors (number of fishers and distance) for Taiwan's pre-CITES imports, no predictors were significant for Taiwan's imports in the post-CITES period (Table 2).

In Hong Kong's Customs data, for both pre-CITES and post-CITES period, more seahorses reportedly arrived from the source countries with fewer fishers ($p < 0.01$), lower per capita GDP ($p < 0.01$), higher demersal fish catch (pre-CITES: $p = 0.03$; post-CITES: $p < 0.01$), and shorter distance from Hong Kong (pre-CITES: $p = 0.02$; post-CITES: $p < 0.01$) (Table 2).

In Taiwan Customs data, more seahorses were putatively imported from source countries with more fishers ($p = 0.02$) and closer to Taiwan ($p < 0.01$) in the pre-CITES period (Table 2). No predictor was found significant for Taiwan's imports post-CITES (Table 2).

For all pairs of countries trading seahorses post-CITES, reported volumes were higher from source countries with lower per capita GDP ($p = 0.02$) and higher demersal fish catch ($p < 0.01$), to destination countries that also had higher demersal catch ($p < 0.01$) (Table 2). The analysis of CITES data also showed that countries with shorter distance between each other recorded trading more seahorses ($p < 0.01$). Fewer seahorses were recorded traded over the years ($p < 0.01$).

4. Discussion

In this first analysis of the changes in global trade associated with CITES listing for marine fishes, changes in various aspects of global seahorse trade were identified in the post-CITES period. More rapid declines in the documented trade volume of wild-caught seahorses, fewer source countries, and increases in recorded prices were found after CITES interventions, similar to the findings in the live reptile trade [44]. In addition, the range states that ever reported exporting seahorses were generally found to have larger demersal fisheries catch, highlighting the importance in managing such non-selective fisheries for sustainable seahorse trade [32]. However, those countries continuing the trade after CITES implementation did not always invest greater efforts in ensuring sustainable fisheries. The bilateral seahorse trade volume correlated with geographic distance and the scale of marine fisheries and national economics, which was consistent with other studies on seafood trade [37]. These results provide insights in examining the changes in trade under CITES regulations, predicting changes in seahorse trade volumes, and identifying potential underreporting [11,41,42].

The analyses in this study provided strong evidence of the CITES interventions correlated with steeper declines in declared trade volume of wild seahorses, consistent with the trend found in some other CITES listed species [44,56]. Although this does not mean that there was no other factor of the declining trade volume, the more rapid declining trend after listing could have arisen from three national responses to the CITES implementation: (1) some countries managed to properly control their export trade in wild seahorses, (2) some countries officially suspended seahorse exports and (3) some trade proceeded without permits, disappearing from formal statistics:

(1) Some countries managed to properly control their export trade in wild seahorses. The first possible response, CITES member countries

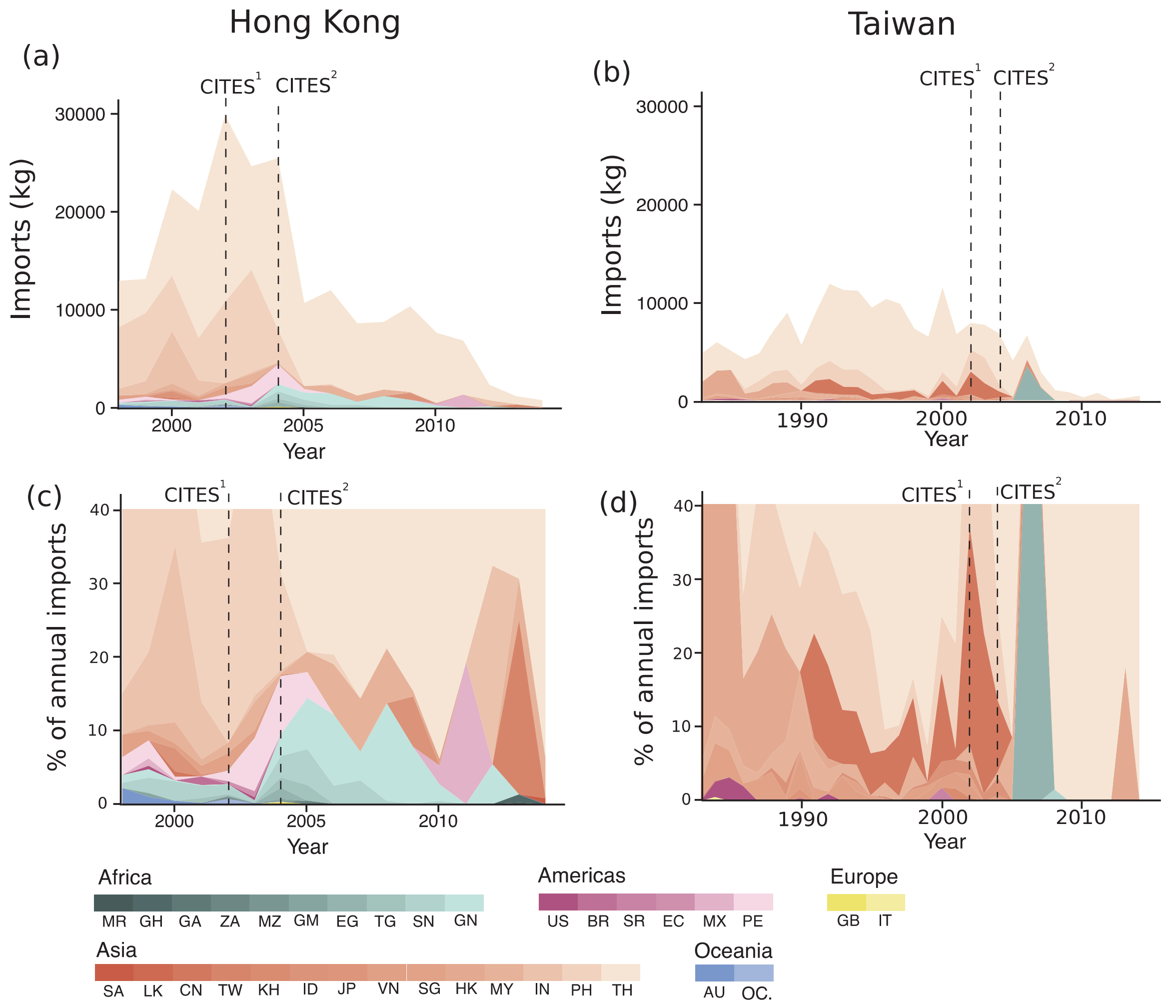

Fig. 4. The import weights of dried seahorses from each source country for (a) Hong Kong and (b) Taiwan from the Customs data. To see the changes in the imports from minor source countries, the cumulative imports to 40% of total imports are shown in (c) and (d), for Hong Kong and Taiwan respectively. Each country is labeled by its 2-digit ISO code, and the full names of those countries are listed in Table C1. The year of CITES listing (2002, CITES^1) and implementation (2004, CITES^2) are labeled.

meeting their CITES obligations, was unlikely for the exporters that are big enough to affect global trade statistics. In particular, Thailand, which generated 60% of Hong Kong's imports and 70% of Taiwan's before CITES listing, was repeatedly given formal recommendations by CITES because it failed to meet its obligation to the Convention [15, 24].

(2) Some countries officially suspended seahorse exports. In accordance with the proposed second response, country suspensions, some other big traders ceased exporting after CITES listing, either because of national rules or because of difficulties in meeting obligations. For example, the Philippines' Fisheries Act forced automatic suspension of extraction and trade for all CITES listed-species, regardless of the Appendix. In contrast, Malaysia suspended trade actively when confronted with a Review of Significant Trade for seahorses, apparently concerned about making reliable non-detriment findings. Other countries have suspended trade for other taxa under similar circumstances, as with some stony coral species in Indonesia [52]. Yet another source of trade suspensions were CITES decisions to suspend exports from CITES member countries that were having difficulty meeting their obligations, as for *Hippocampus kuda* from Vietnam (2013) and for *Hippocampus algiricus*. Eventually Thailand, too, suspended seahorse exports, in January 2016 (too late to be in the database at present), when confronted with ongoing challenges in achieving remedial measures recommended by CITES.

(3) Some trade proceeded without permits, disappearing from formal statistics.

With respect to the third response, of illegal exports, it is clear that there were regulatory failures in some countries. For example, Project Seahorse trade surveys in Thailand identified considerable illegal and unreported trade at the borders.

Shifts in the declared trade routes of dried seahorses highlight the importance of enhancing tracing specimens in trade in order to guide conservation efforts [38,57]. This study found increasing proportions of seahorses imported from African countries to Hong Kong SAR and Taiwan in the post-CITES period, though such a shift may be transitory. Given that the gravity model analysis showed that the import countries had strong preferences for sourcing seahorses from regions closer to them, sourcing animals from regions further away might reflect serial exploitation [3,45]. It may also reflect established routes for other goods and services. While mainland China, another large market for seahorses, has enhanced its trade relationship with African countries in recent years, it's possible that mainland China could also have expanded its seahorse sourcing from Africa as with other natural resources, such as crude oil and timber [10]. In addition to the changes in source countries, Hong Kong SAR Customs showed that China was no longer the biggest reported destination of seahorse re-exports from Hong Kong after 2002. This might be because traders transporting seahorses to mainland China stopped reporting, or Hong Kong's exports were transported to other countries, as seen in the shark fin trade [57]. All the changes in the complex trade routes demonstrated a dynamic

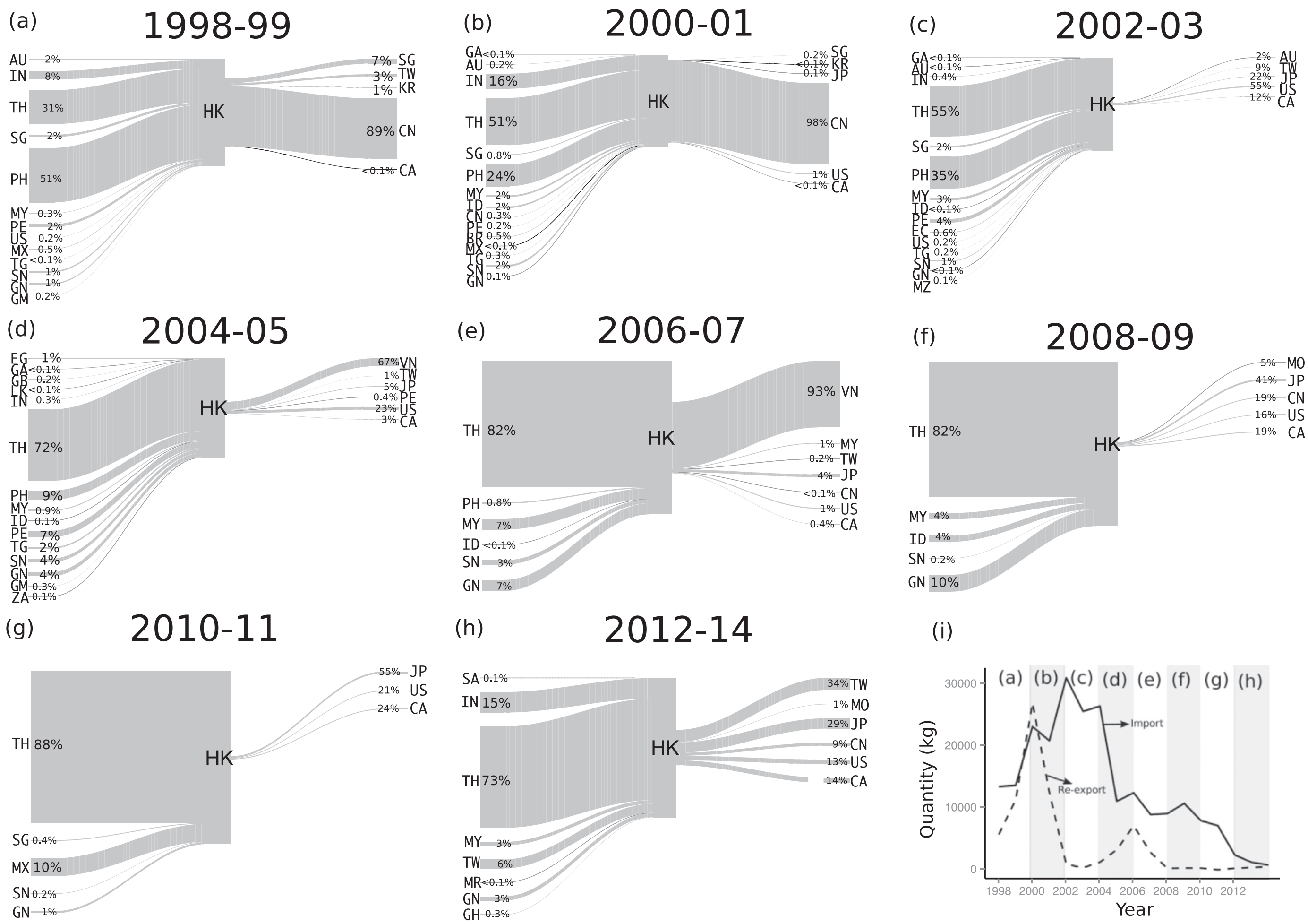

Fig. 5. Changes in the proportions of dried seahorse imported to Hong Kong from each source country and re-exported to each destination country. (a)-(h) show the relative imports and re-exports for every two years, and (i) shows the absolute import and re-export weight overtime. Each country is labeled by its 2-digit ISO code, and the full names of those countries are listed in Table C1.

trading network that needs continuous and close tracking.

Despite the declining recorded trade volume, increasing prices for seahorses suggest further threats to seahorse conservation [50]. Hong Kong Customs' data showed an increasing trend in the seahorse import prices, consistent with several on-site observations of seahorse trade (data, [46] and trends in prices of other endangered animals [12,26]. The coincidence of increases in prices with decreases in recorded exports suggest that the demand was not satisfied, and may still be growing with China's thriving economy [58]. While rare wild animals were often popular in the luxury markets, the higher prices of endangered species could provide greater incentives for humans to continue extracting the species [17]. Although seahorses are mainly sourced incidentally, it is possible that high price can motivate a shift to target fishing, which may raise conservation concerns [34].

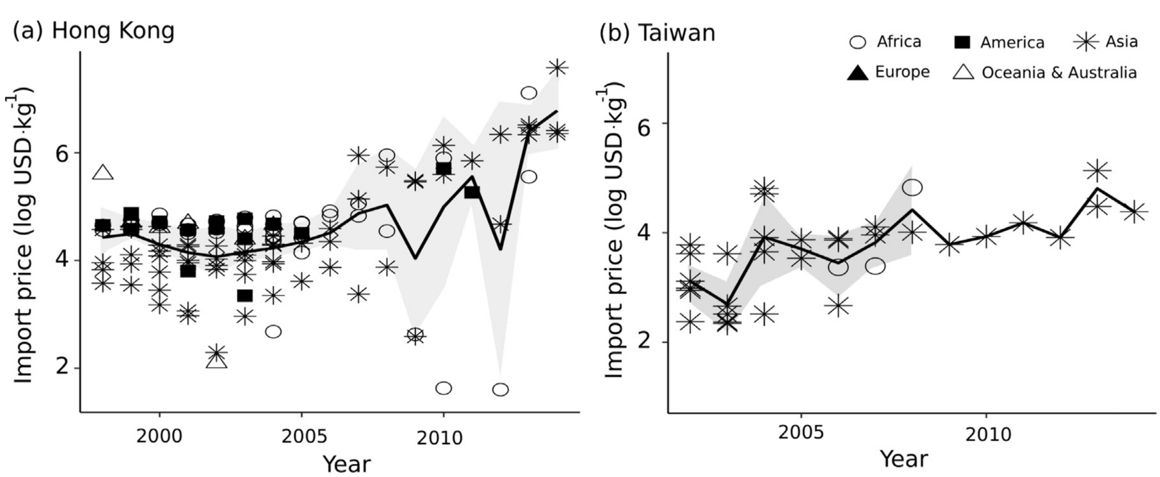

Fig. 6. Changes in the import prices of dried seahorses for (a) Hong Kong and (b) Taiwan. Prices for seahorses from each continent are presented in different shapes. Lines show the mean price of all source countries for each year, with 95% confidence intervals in grey.

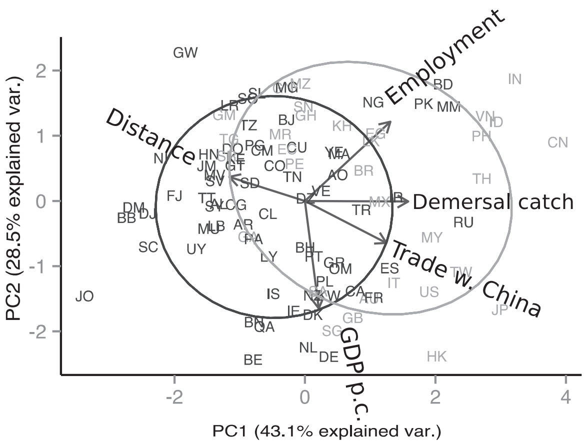

Fig. 7. Comparisons of dried seahorse source countries (grey, n = 32) and non-source countries (black, n = 68) on the space of the first two principal components. Variables used in the PCA included demersal fish catch (Demersal catch), general trade value with China (Trade w. China), per capita GDP (GDP p.c.), marine fisheries employment (Employment), and distance to China (Distance).

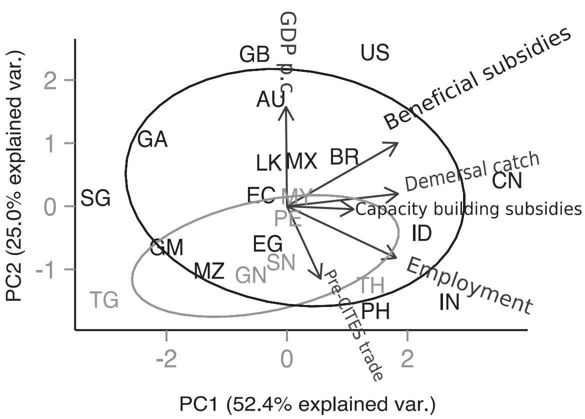

Fig. 8. Comparisons of seahorse source countries that continued their exports (grey) and the countries that stopped exporting seahorses after the CITES listing (black). Variables used in the PCA included demersal fish catch (Demersal catch), per capita GDP of each source country (GDP p.c.), the average seahorse trade volume in the pre-CITES period (pre-CITES trade), marine fisheries employment (Employment), subsidies for fisheries capacity building (Capacity building subsidies) and beneficial fisheries subsidies (Beneficial subsidies).

This study shows that some countries with very limited investment in sustainable fisheries were exporting seahorses, posing questions about implementation of CITES at national levels. Seahorse source countries tended to be more involved in demersal fisheries than other range states, as might be expected from previous studies showing that most seahorses were caught incidentally in demersal fisheries [32]. Such sourcing means that to ensure the sustainability of seahorse trade, effective management of the demersal fisheries is critical [32]. However, as a country's efforts in managing sustainable fisheries was not found correlated with changes in its seahorse exports, continuing seahorse trade under CITES regulations might be more determined by economic incentives and trade inertia [7]. CITES member countries need to pay full attention to meeting the requirement that they make non-detrimental findings for seahorses, as for other taxa [1].

Comparisons of different source countries and the results of gravity models among datasets provided insights about potential sources of under-reporting. In contrast to Taiwan's imports and CITES global trade records, Hong Kong's imports were inversely related to the number of fishers in the source countries. This is mainly because Hong Kong reported small imports from countries with large numbers of fishers (e.g., Brazil and Indonesia) which did not appear in Taiwan's Customs and the CITES database. The small reported imports from those countries, comparing to other countries with similar number of fishers, may be explained two ways: (1) imports from these countries are very under-reported/and or (2) these countries retain a significant amount of seahorse catch in their domestic market, such that it is not detected in international trade records. The latter would certainly be likely for Indonesia and perhaps for Vietnam [53]. Domestic trade also distorts global trade figures for mainland China. In the CITES database, it reported importing fewer seahorses than much smaller Hong Kong SAR and Taiwan. It turned out that China's consumption of ten tonnes of seahorses annually was largely derived from domestic waters and fishers brought back from other oceans [27], in addition to potential illegal trade.

Although the global seahorse trade was found changing with CITES intervention in several aspects, the results of this study have to be interpreted with caution. First, the correlations between changes in trade and the CITES interventions are not necessarily indicating direct cause and effect. For example, the declining trend in trade volume may be caused by declining seahorse populations, rather than trade regulations. Unfortunately, the seahorse population time series is currently unavailable for testing the impacts of changes in wild population on trade volume. Second, the trade volume documented in Customs records and the CITES trade database might be largely underestimated, since the declared trade data did not include (probably increasing) illegal and unreported trade. While the CITES trade database only recorded an average of seven million dried seahorses in trade, a meta-analysis shows that at least 37 million seahorses were caught incidentally every year [32]. While some of those seahorses might be discarded, most probably went into domestic trade (in just a few countries) or were exported illicitly [32]. Studies on other wildlife have shown that illegal trade could continue even when the exports were suspended, and those trades would not be captured by official data [12]. Overall, declared trade data, though underestimated and full of discrepancies, still has great potential for systemically and quantitatively examining policy impacts on trade on large temporal and spatial scales [11,3,40].

5. Conclusion

This study shows that documented international trade in seahorses changed after the implementation of the CITES listing, such that trade monitoring is clearly important for adaptive management. The import prices of seahorses rose with declines in declared trade volume, providing incentives for illegal catch/hunting [17,36]. In addition, a major seahorse importer, Hong Kong, was found to have expanded its sources to include a number of new African and South American countries, even though it might just have been temporary. Such expansion highlights the need to invest conservation efforts on new source countries, especially given that many countries that were hitherto major sources for seahorses have officially suspended or banned their exports [24]. This study also found that even under CITES regulations, exports of seahorses were mainly affected by the economic status of the source countries rather than investment in management efforts therein.

Having shown that recorded trade has changed with an international environmental agreement, it will need to deduce whether such agreement reduced pressure on wild populations. A species listing on Appendix II is merely a call to action. The value of the listing lies in its implementation. Thus far most legal trade in seahorses has been suspended, either voluntarily or involuntarily [24]. For example, outside the time frame covered by the reported CITES data, CITES decided to suspend exports from Senegal and Guinea for one seahorse species, in January 2016. This, combined with the closures of exports from Malaysia, the Philippines, Thailand, Vietnam (one species), and other countries creates a situation where 96% of previous global trade in seahorses would not be permitted. The question is whether this trade has indeed ended or merely been redirected through illegal channels. Given the ongoing capture of huge numbers of seahorses in nonselective gear, the former seems more likely, which highlights the need to find

Table 2
Results of gravity model for Hong Kong's dried seahorse imports (Hong Kong CSD data), Taiwan's dried seahorse imports (Taiwan Customs), and global bilateral dried seahorse trade (CITES data). Hong Kong and Taiwan's imports in pre-CITES implementation (pre 2005) and post-CITES implementation (2005–2014) periods were separated in order to compare with the CITES data (2005–2014). Sample size (n) included trade volume = zero (set as 10^{-10}) for potential country pairs in trade (see Methods). All variables were in logarithm space.

		Hong Kong 1998–2004			Taiwan 1983–2004					
		Estimate	SE	P-value	Estimate	SE	P-value			
	(Intercept)	9618.40	36,386.75	0.79	− 6491.53	31,318.92	0.84			
Source	# of fishers	− 4.49	1.36	**< 0.01**	1.64	0.69	**0.02**			
	GDP per capita	− 3.99	0.88	**< 0.01**	− 0.43	0.64	0.5			
	demersal fish catch	3.13	1.32	**0.03**	− 0.56	0.76	0.47			
Destination	# of fishers	301.65	382.4	0.43	− 49.14	328.13	0.88			
	GDP per capita	56.37	86.72	0.52	1.8	7.27	0.81			
	demersal fish catch	− 17.02	12.65	0.18	8.75	6.96	0.21			
	Distance	− 3.47	1.47	**0.02**	− 5.23	0.92	**< 0.01**			
	Year	− 1659.54	5142.56	0.75	922.56	4651.58	0.84			
n			189			352				
R-square			0.2			0.2				
		Hong Kong 2005–2014			Taiwan 2005–2014			CITES (global) 2005–2014		
		Estimate	SE	P-value	Estimate	SE	P-value	Estimate	SE	P-value
	(Intercept)	17,141.01	56,215.85	0.76	6468.4	31,395.8	0.84	522.35	154.64	**< 0.01**
Source	# of fishers	− 4.84	1.03	**< 0.01**	0.16	0.76	0.83	− 0.16	0.19	0.38
	GDP per capita	− 3.39	0.61	**< 0.01**	− 0.43	0.72	0.55	− 0.49	0.16	**0.02**
	demersal fish catch	4.66	0.93	**< 0.01**	0.91	0.72	0.21	0.62	0.23	**< 0.01**
Destination	# of fishers	290.4	825.11	0.73	− 471.88	963.89	0.63	0.06	0.14	0.64
	GDP per capita	− 26.81	57.18	0.64	17.47	26.79	0.52	0.21	0.32	0.50
	demersal fish catch	15.98	33.4	0.63	− 3.71	12.44	0.77	0.37	0.15	**0.01**
	Distance	− 3.52	1.03	**< 0.01**	− 0.33	1.07	0.76	− 3.14	0.84	**< 0.01**
	Year	− 2582.88	8280.83	0.76	− 85.29	5326.28	0.99	− 0.26	0.08	**< 0.01**
n			270			160			1639	
R-square			0.26			0.07			0.05	

ways to address bycatch of species listed on the Appendices. More effort needs to be applied to analyzing and combating illegal, unregulated, and unreported trade and to addressing bycatch sourcing for marine fishes [24].

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2017.10.031.

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